The Effect of Railway Route Extension on Housing Price: – Focusing on Ilsan Newtown -

By

JIN, Yeontaek

THESIS

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF DEVELOPMENT POLICY

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Committee in charge:

Professor Cho, Man, Supervisor ________________________

yangheeseung

Professor Yang, Hee-Seung ________________________

Approval as of December, 2019

Abstract

The Effect of Railway Route Extension on Housing Price:

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This paper examines changes in housing values associated with route extensions of a public rail service in South Korea. The purpose of this study is to analyze the causal impacts of the second opening of Gyeongui Line (first route extension) and the opening of Gyeongui-Jungang Line (second route extension) on the apartment prices in Ilsan Newtown. This study defines the treatment and control groups depending on geographical proximity to rail stations, and tests the net impacts of the extensions using the difference-in-differences model. It collected the transaction data from 2012 to 2015 provided by the Ministry of Land, Infrastructure, and Transport in South Korea. This study finds that the first and second route extensions of the rail service have positive effects on the apartment prices that fall within 800 m distance from rail stations, and higher treatment effects are found from the second extension. These findings suggest that the increase in accessibility to distant areas through railway line extensions have positive effects on the regional values in the metropolitan area.

Keywords: railway route extension, housing values, difference-in-differences

Acknowledgement

I would first like to show my sincere gratitude to Professor Man Cho and Professor Hee-Seung Yang, my thesis supervisors, for their professional guidance and warm encouragements. They have always given insightful comments whenever I had questions about this research, and helped me write this paper in the right direction. I am also grateful to Wonhyeop Shin and Andrey Ten who provided me valuable comments and suggestions during the early phase of this work. Thanks to their advice and help, this research could be designed and progressed with an effective way. My grateful thanks are also extended to Rovil Espiritu who has given the great services on proofreading and editing. Further, I would like to thank my schoolmates who have shared precious memories together at KDI School of Public Policy and Management. Last but not least, this paper would not have been possible without the love and support of my family. I wish to express my deepest gratitude to my parents and families for their love and assistance.

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I. Introduction

An urban railway plays an important role in the public transportation system of South Korea. The government of Korea has established the urban railway system since the early 1970s to expand the transportation system and to solve urban issues, such as traffic congestion, housing shortages, and environmental problems. The development of the urban railway system has provided people with better access to workplaces and distant areas, complementing the overland transportation system and improving the traffic conditions. Many people have been using the various rail services developed across South Korea, including Seoul and other metropolitan areas.

The benefits of the rail system are transferred to real estate values. Rail system generally improves the accessibility to distant areas, and promotes developments of residential, public, and commercial facilities around rail stations. Accordingly, it leads to the changes in land and housing values around rail stations. In Seoul and other metropolitan areas, housing prices are different depending on the geographical distances to rail stations.

Development of rail system affects land use patterns and property values, so it could be a major concern for urban or transport planners. Since the effects of rail services on housing prices are present in various ways over a long period of time, it is crucial to empirically analyze and evaluate them. Although much has been written about the effects of newly developed rail systems on housing values, there is a lack of research in analyzing the impacts of route (network) extensions of existing rail system on those values. Besides, there is little research yet on rail policies on the northern metropolitan area of South Korea.

This study focuses on the second opening of Gyeongui Line system (first extension) and the opening of Gyeongui-Jungang Line system (second extension), and tests how those route extensions affect housing prices in the Ilsan district, which is the major planned new town in the northern metropolitan area. Thus, the purpose of this study is to empirically analyze the causal impacts of the rail system's route extensions on the price variations of housings. It examines whether the increase in accessibility to Seoul and distant areas leads to the change in the regional values of certain areas in the Ilsan district.

This study examines only apartments, given that apartments account for over 60 % of the entire housing types in South Korea and have structural similarities compared to other types of housings (National Statistics Office of South Korea, 2017). With the assumption that housing prices decline as the accessibility to rail stations becomes lower, this study tests price variations of the apartments between the areas that are close to, and those that are far from rail stations. To do this, this study uses difference-in-differences model (DiD model) that helps analyze the causal effects of policy interventions (Callaway and Santa Ana, 2018). This approach captures the net impact of the route extensions on the changes in the apartment prices, by removing confounding factors (Lecner et al., 2015).

Focusing on the areas in the north of the railway, this study examines the apartment prices in Tanhyeon, Ilsan, and Jungsan-dongs (villages) by using the real transaction data provided by the Ministry of Land, Infrastructure and Transport in South Korea. It defines the treatment and control groups, depending on whether the areas are likely to receive the treatment effects of the rail system. Apartments that fall within an 800 m distance from Tanhyeon or Ilsan stations are the treatment group, while apartments in Jungsan dong are the control group. This study excludes the apartments located in the south of the railway, considering that the impacts of the rail system are duplicated with those of the subway line 3. Focusing on the first and second extensions that were completed in December 2012 and December 2014, this study examines price variations of the apartments in the two study groups before and after the extensions. It focuses on the period from September 2013 to August 2014 for the first treatment effect, and the period from October 2014 to September 2015 for the second treatment effect.

This study finds that the first extension (second opening of Gyeongui Line) and the second extension (opening of Gyeongui-Jungang Line) increase the apartment prices in the treatment group by 2.6% and 5.9%, compared to those in the control group. In terms of size of properties, these impacts are 1.5% to 5% higher on medium-large-sized (area of exclusive use > 60m^2) apartments than small-sized (area of exclusive use <= 60m^2) apartments.[1] Those route extensions also create different treatment effects by region and time.

Following Section I Introduction, related studies on the relation between rail systems and real estate values are addressed in Section II. Meanwhile, Section III provides an overview of Ilsan district and Gyeongui-Jungang Line, and Section IV discusses the data collection and the empirical strategy of this study. Section V shows the impacts of the network extensions on the apartment prices, and addresses the robustness test and heterogeneity effects. Conclusion and discussion are addressed in Section VI.

II. LITERATURE REVIEW

2.1 Overview

Accessibility to public transport systems affects property values. Improved proximity brought by public transportation creates the capitalization effect which is absorbed into changes in housing prices around transport systems (Edel and Scar, 1974; Henneberry, 1998). Many empirical studies have identified price differences of housings, depending on the accessibility of rail stations. Based on this, this section provides an overview of the concepts of station-influence area, and examines previous studies that identify the relationship between

[1] Area of exclusive use refers to spaces that each household uses independently. It involves the areas of living room, kitchen, bathroom, toilet, and bedroom. Areas for common spaces such as corridors, staircase, and elevators are not included. In terms of sizes, the Ministry of Land, Infrastructure, and Transport in South Korea has specified housings with area of exclusive use less than 60 m^2 as small-sized housings.

the development of rail systems and housing prices.

2.2 Definition and scope of station-influence area

Numerous studies have attempted to define station-influence area in various ways, according to spatial characteristics and development levels of cities.

Station-influence area has usually been defined in terms of pedestrian's accessibility and land use change. According to The Seoul Institute (1998), station-influence area is a spatial extent where pedestrians access rail stations by walking, and promotes practical use of lands around the area by developing residential, public and commercial facilities. Han (1991) also defines it as a sphere that generates and enlarges demands of commuting passengers using railroads. The Korea Research Institute for Human Settlement (2004) addresses economic aspects, arguing that the area is heavily affected by the changes in the real estate value, such as land values and housing prices.

Yeon (1996) states the general characteristics of station-influence area. First, station-influence area has a large number of commuting population, and affects land use patterns around the area by developing various facilities. Second, station-influence area serves as a hub for regional development. Positive economic externalities in the area spill over into neighborhood areas through active personal and commercial exchanges, thereby contributing to regional developments at distant areas. Lastly, high population density and ineffective development in station-influence area could cause urban problems, such as traffic jams, housing shortages, and environmental pollutions.

Regarding the geographical scope of station-influence area, Seoul Metropolitan City Basic Plan (1997) categorizes the geographical range within 500 m radius from rail stations as the primary influence zone, and that between 500 m and 1,000 m as the secondary influence zone. Third Subway Basic Plan (1992) of South Korea considers the geographical conditions of lands and territories around rail stations, and specifies the range between 200 m and 800 m radius from rail stations as station-influence area. In case of foreign countries, Tokyo and Los Angeles use 700 m and 800 m linear distance to rail stations in metropolitan areas, respectively, considering topographical obstacles (Lee, 2004; The Seoul Institute, 1997). Hence, station-influence area has been diversely defined depending upon region, time, and the type of measurement.

2.3 Rail system developments and housing values

Several empirical studies have analyzed the impact of rail systems on land use change or housing prices. Cho (2010) analyzes the accessibility benefits of rail systems on prices of apartments in 2003 and 2008, targeting Gangnam, Bundang, and Nowon districts. Using the hedonic model, the study finds that the impacts of the accessibility to the rail stations are different by time, district, and sizes of apartments. While the decrease in proximity to rail stations in Gangnam district negatively affected the apartment prices during the two years, the apartment prices rather increased in Bundang and Nowon districts when the accessibility is lowered. The study argues that apartment prices are affected not only by the proximity of rail stations, but also by other factors, such as the location of education facilities or the environments around rail stations. Choi and Sung (2011) examines the impacts of subway line 9 on housing values by development phases. By assuming that the impacts on housing prices appear prior to opening of the rail service, the study classifies the development phases into five and analyzes effects of each phase. Using the hedonic model, the study finds that an anticipation effect of the rail system begins to affect housing prices before the planning stage, while the influences rise and fall by time and location.

Regarding researches that apply difference-in-differences model (DiD model) to measure the causal effect on real estate values, Bae (2017) tests the effect of the Sinbundang subway line development on price changes of apartments in Suji-gu in Yongin City, focusing on the construction and opening phase of the rail system. The study finds positive impacts on the apartment prices in the treated zone during the both phases, and the positive impacts are over 2% higher when the treatment zone is within 1,000 m from the subway station than it is within 500 m. Diao et al (2017) empirically test the impact of the opening of the new Circle Line (CCL) on private housing values in Singapore. This study uses spatial DiD model to address possible spillover effects from the treatment zone to neighborhood properties in the control zone. The study finds out that the opening of the rail service leads to approximately 8.6 % increase in housing values in the treatment zone compared to that in the untreated zone.

Based on other empirical studies analyzing the effects of newly developed rail systems on housing prices, this study discusses whether the increase in accessibility through railway route extensions has economic effects on the regional values in the northern metropolitan area. Many previous studies in South Korea have used linear distance (Euclidean distance) to rail stations, when measuring the proximity of rail stations. Considering that topography around rail stations is not flat and characterized by complicated features, this approach could cause measurement errors and biased estimation (Diao et al, 2017). Hence, this study uses actual walking distance (network distance) to prevent measurement errors concerning topographical features around rail stations.

III. Overview of Gyeongui-Jungang Line and Ilsan Newtown

3.1 Gyeongui-Jungang Line

Gyeongui-Jungang Line is a wide area rail system which passes through the northern metropolitan areas of Paju, Goyang, Seoul, Guri, and Namyangju in South Korea. With a total of 55 stations, the railroad system has been extended since 2010, integrating the three individual rail systems: Gyeongui Line, Yongsan Line, and Jungang Line.

During the early 1900s, Gyeongui Line played as the major rail system in Korea, by connecting Seoul and Sinuiju area. After the Korean War, the demand for the railway decreased, so the service was rarely used until the 1980s. Along with the development of Ilsan Newtown and other metropolitan areas, KORAIL (Korea Railroad Corporation) incorporated Gyeongui Line into the Seoul Metropolitan Subway system, by enlarging the rail service with a double-track line system. The first opening of Gyeongui Line with the double-track line system occurred in July 2009.

In December 2012, the service was enlarged through the integration of Yongsan Line which connected Gajwa and Gongdeok stations. It helped reduce the traveling time from Ilsan district to Seoul or distant areas, through Hongik University station (subway line 2, airport railroad line) and Gongdeok station (subway line 5, 6). After the first extension, the railway was again integrated with Jungang Line in December 2014, and the rail service began to pass through Seoul and major northern metropolitan areas, such as Yongsan, Wangsimni, Guri, and Namyangju. The first and second route extensions of the rail system boosted the accessibility convenience of people and contributed to regional developments around the rail stations. Along with the expanded rail service after those extensions, the number of the rail users at Ilsan district increased after 2010.

Gyeongui-Jungang Line has a total of 128 km length, and the traveling time from Munsan (Paju) to Jipyeong station (Yangpyeong area) is about 2 hours and 40 minutes. The rail system operates from 5 am to around 1 am every day, and also provides the express rail service. The time interval of the trains is about 9 to 10 minutes during rush hour and 10 to 20 minutes at other time slots. Jipyeong station was added in January 2017, and an extension project connecting Munsan and Dorasan stations at Paju area has been proposed recently.

Table 3.1 Overview of Gyeongui-Jungang Line

Event	Extended with	Route (stations)	Date
First opening of Gyeongui Line (46.3 km)	-	Munsan --- Seoul	2009.07
Second opening of Gyeongui Line (First extension, 53.3 km)	Yongsan Line	Munsan --- Gongdeok	2012.12
Gyeongui-Jungang Line Opening (Second extension, 128.1 km)	Jungang Line	Munsan --- Yongmun	2014.12

Source: Data from Korea Railroad Corporation. Note: The rail services in the table are all run by the Seoul Metropolitan subway system. Yongsan Line originally passed by Gajwa, Hongik University, Sogang University, Gongdeok, Hyochang Park, and Yongsan stations. In 2012, Gyeongui Line was integrated with Yongsan Line (second opening of Gyeongui Line), but operated the rail service up to Gongdeok station. In December 2014, it was integrated again with Jungang Line (74.8 km) through Yongsan station. Even after the extensions, the service bound for Seoul station has still been provided together.

3.2 Ilsan Newtown

Ilsan Newtown is one of the first planned new towns designed to increase housing supplies and to alleviate the overpopulation in Seoul during the 1980s and 1990s. As one of the districts in Goyang city, Ilsan Newtown is comprised of Ilsanseo-gu (Ilsan Western district) and Ilsandong-gu (Ilsan Eastern district), and has many modern facilities compared to Deogyang district which has been the old town of Goyang city. Like the other planned new towns in Bundang or Pyeongchon area, Ilsan Newtown functions as a satellite city that lessens the residential and administrative burdens of Seoul. Regarding the rail transportation system, subway line 3 serves as the main transportation system in the area and passes through the major areas of Ilsan district, such as Jeongbalsan and Madu. Many public and commercial facilities have been constructed and developed around the subway line 3 since the initial phase of the city's development. Gyeongui-Jungang Line is placed on the northern part of the district, and has enlarged the rail services since 2010. There are five rail stations of Gyeongui-Jungang Line in Ilsan district: Tanhyeon, Ilsan, Pungsan, Bengma, and Goksan stations.

3.3 Focus areas: Tanhyeon, Ilsan, and Jungsan-dongs (village)

This study focuses on the apartments located in the north of Gyeongui-Jungang Line, since the areas in the south of the railroad could be affected by the subway line 3. Considering the impacts of Gyeongui-Jungang Line on housing prices could be overlapped with those of subway line 3, the apartments in the south are ruled out in this study. Based on this, this study addresses the apartments in Tanhyeon, Ilsan, and Jungsan-dongs that have many apartment complexes, as shown in Figure 3.1.[2]

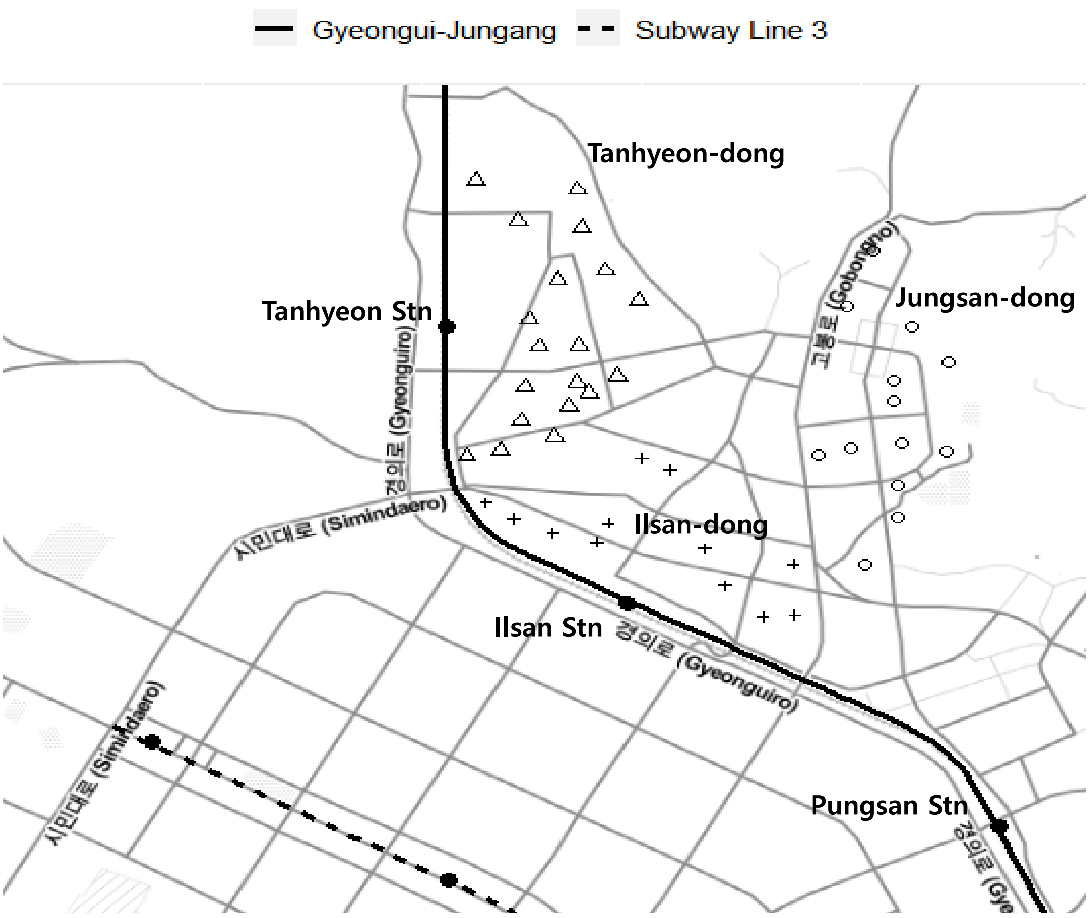

Figure 3.1 Research scope in Ilsan district. Source: Illustrated by the author using the coordinate information from Google Map. Note: Based on the study boundary, "△", "+", and "○" denote the apartment complexes in Tanhyeon, Ilsan, and Jungsan-dongs, respectively. The name of Simin-daero was changed into "Goyang-daero (Goyang Boulevard)" after 2011.

[2] Given that there are few neighboring apartment complexes around Pungsan, Bengma, and Goksan stations, this study only focuses on the apartments near Ilsan and Tanhyeon stations.

Tanhyeon-dong and Jungsan-dong had been rural areas until the 1980s, but were urbanized around the same time of the development of Ilsan Newtown. For this reason, they share similar regional and housing characteristics. These two villages have many apartment complexes built during the 1990s and have convenient facilities, such as neighborhood parks and community centers. While the two villages have a large number of population and households, the population density is lower than the other areas in Ilsan district.

Ilsan-dong consists of three sub administrative dongs: Ilsan1, Ilsan2, and Ilsan3-dongs.[3] This study only addresses Ilsan1-dong and Ilsan2-dong, and specifies those as "Ilsan-dong." Since Ilsan-dong functioned as the center of Ilsan old town in the past, there are many old buildings and facilities around the village. Despite the small land area, new apartments and high-rise buildings have been densely built around Ilsan station since 2000, so they have a high level of population density compared to other areas in the district, as shown in Table 3.2. Ilsan-dong also has a traditional market (Ilsan Market) and hospitals for the elderly (such as Ilsan Western Health Center and Ilsan Gospel Hospital). In terms of the population by age group, Ilsan and Jungsan-dong generally have a high rate of population aged over 50s, while Tanhyeon-dong has many people in their 30s and 40s.

Table 3.2 Population composition at the four villages (2015)

Village (dong)	Area (km^2)	Total Population	Men	Women	Population Density (population/km^2)
Ilsan 1	0.65	30,410	14,813	15,597	45,828
Ilsan 2	0.82	21,268	10,516	10,752	25,152
Tanhyeon	2.19	50,551	24,773	25,778	22,740
Jungsan	2.84	44,727	21,799	22,928	15,529

Source: Computed by the author using Goyang Statistics

[3] Ilsan3-dong is located in the south of the railroad, so it is excluded in this study.

Table 3.3 Population composition by age group (2015)

Village (dong)	Age group			
	0~10s	20s	30s~40s	Over 50s
Ilsan 1	22.73 %	13.56%	33.22%	30.49 %
Ilsan 2	18.61 %	14.96 %	30.81 %	35.62 %
Tanhyeon	24.47 %	13.47 %	35.86 %	26.2 %
Jungsan	21.18 %	13.28 %	31.07 %	32.67 %

Source: Computed by the author using Goyang Statistics

For the housing supply, the number of housings and households at the four villages increased in 2015, compared to 2010. As of 2015, Ilsan1-dong has the highest diffusion ratio of house, followed by Tanhyeon, Jungsan, and Ilsan2-dong. Table 3.4 shows that the diffusion ratio of house at Jungsan-dong declined from 89 % in 2010 to 88 % in 2015, due to the slow growth in the number of housings. In terms of the housing types, apartments are highly supplied at the four villages and account for over 80 % of total housing types, followed by single-family house (11%), multiplex housing (1.6%) and row house (1.57%).

Table 3.4 Diffusion ratio of houses at the four villages

Village (dong)	Year	Number of housings	Number of households	Diffusion ratio (%)
Ilsan 1	2010	8,227	8,503	96.75
	2015	9,230	9,386	98.34
Ilsan 2	2010	6,034	7,127	84.66
	2015	6,324	7,428	85.14
Tanhyeon	2010	11,817	12,971	91.10
	2015	15,111	16,299	92.71
Jungsan	2010	12,649	14,130	89.52
	2015	13,329	15,091	88.32

Source: Computed by the author using data from Gyeonggi Traffic Control Center. Note: Diffusion ratio of house is computed by total number of housings divided by total number of households.

Education facilities have also been developed around the villages. This study in particular discusses innovation elementary schools that could affect housing prices. Innovation school helps develop the creativity and learning effects of students via selfdirected learning and enhanced autonomy of teachers (Kim, 2011). Despite the controversy over the effectiveness of the curriculum, the number of innovation schools has been increasing since 2010. In Goyang city, if an elementary school is designated by the government as innovation school, apartments in the surrounding areas are assigned to the innovation school. People who live in the assigned apartments are the priority when sending their children to innovation schools. Due to the increased popularity of the schools, there are price differences between apartments that have the priority and those that do not have, in some regions. Based on this, this study tests whether elementary innovation schools affect the apartment prices in the villages. As shown in Table 3.5, there are two innovation elementary schools in the study boundary, and a total of 19 apartment complexes are assigned to the innovation schools.

Table 3.5 Innovation elementary schools in the study boundary (as of 2018)

Name of innovation school (Elementary)	Designated day	Location	Number of assigned apartment complexes
Sangtan elementary school	2011.03	Tanhyeon-dong	11
Jungsan elementary school	2015.03	Jungsan-dong	8

Note: The innovation elementary schools are based on the study boundary, which includes Tanhyeon, Ilsan1, Ilsan2, and Jungsan-dongs (villages). This study only examines elementary schools, due to the fact that the assignment for innovation middle schools is determined by a lottery system. The data are obtained from each elementary school website.

IV. Data and empirical strategy

4.1 Data

This study uses the real transaction data provided by the Ministry of Land, Infrastructure and Transport in South Korea. The data also contain information on date of transaction, age of apartments, floor, and area of exclusive use. To obtain further information on housing characteristics such as room, bath, building to land ratio, household numbers, and entrance type, this study uses the data from Kookmin Bank (KB) Real Estate. It also measures distances from an apartment to elementary schools and bus stops by using the map data of Naver, which is the Korean internet portal service. This study targets the apartments built between 1990 and 2005 with area of exclusive use below 135 m^2, and excludes high-rise residential buildings. Given that the treatment zone is within 800 m distance from Tanhyeon or Ilsan stations, there are 108 apartment units with 20 apartment complexes in the treatment group, and 119 apartment units with 13 apartment complexes in the control group. From August 2012 to September 2015, the total number of the transaction sample is 4,259 with 2,657 in the treatment and 1,602 in the control groups. The average apartment price per m^2 is 2,817,173 won in total, with 2,868,393 won for the treatment and 2,732,222 won for the control group. There is not much difference in average area of exclusive use between the treatment (75.18 m^2) and control groups (74.90 m^2).

To see different price variations by size of housing, this study also tests the treatment effects targeting small-sized apartments and medium-large-sized apartments. Although official criteria for the size classification does not exist within the housing law in South Korea, the Ministry of Land, Infrastructure and Transport has generally classified the size based on "area of exclusive use." Housings with area of exclusive use below 60 m^2 (18 pyeong) are small properties, and those over 60 m^2 are medium-large properties.[4] In this study, there are a total of 1,732 transactions for the small-sized apartments, with 794 in the treatment group and 938 in the control groups. For the medium-large-sized properties, the total observations are 2,527 with 1,863 in the treatment and 664 in the control groups. Overall, the demands and transactions for medium-large-sized housings were higher than those for small-sized housings.

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[4] 1 pyeong = 3.305785m^2

Table 4.1 Summary statistics

	Full Sample		**Treatment Group (Within 800 m from rail stations)**		**Control Group (Jungsan-dong)**	
Observation	4,259		2,657		1,602	
	Mean	SD	Mean	SD	Mean	SD
Sale Price (won)	208,731,557	56,235,635	214,123,824	49,476,380	199,788,200	64,973,222
Sale Price per square meter (won/m^2)	2,817,173	342,656	2,868,393	352,447	2,732,222	307,607
Ln (Sale price per square meter)	56,335	1,222	56,514	1,224	56,037	1,160
Area of exclusive use (m^2)	75.07	22.64	75.18	17.75	74.90	29.01
Construction year	1998	3.69	1999	3.96	1996	1.81
Floor	9	5.68	10	6.02	7	4.15
Number of households	648	232.71	626	240.16	683	215.22
Apartment Complex (number)	8	4.10	6	2.50	11	4.4
Building to Land ratio (%)	18.95	8.28	19.82	9.93	17.50	3.93
Distance to rail station (m)	1,130	687	620	135	1,973	285
Distance to elementary school (m)	304.29	146.18	294.70	143.66	320.21	148.95
Distance to bus stop (m)	148.09	56.09	145.51	61.10	152.35	46.31

Table 4.2 Transactions by the study group and time

Size of housing	**Group**	**Time**		
		Before (2012.08-2013.07)	**First extension (2013.09-2014.08)**	**Second extension (2014.10-2015.09)**
Small-sized	Treatment	211	266	317
	Control	241	337	360
Medium-large-sized	Treatment	448	591	824
	Control	162	195	307

Note: The table shows the real transaction data during each time slot.

4.2 Treatment zone

This study identifies the geographical scope that receives the treatment benefits of the rail systems. As discussed in Section II, many studies in South Korea have used 500 m or 1,000 m linear distance (10 to 15 minutes to rail stations) as station-influence area. This study defines 800 m network distance as the appropriate treatment boundary, considering that many apartments in the villages are located between 400 m and 800 m from the rail stations, and 800 m network distance is nearly equivalent to 15 minutes maximum walking time to the rail stations.[5] This study expects that the capitalization effects created by the route extensions would be reflected to the apartment prices that fall within 800 m from the rail stations.

4.3 Temporal impact

This study assumes that the first opening of Gyeongui Line had a marginal effect on the housing prices, due to the stagnation of the real estate market from the global economic crisis. Despite the temporal rise, housing prices in the villages generally decreased between 2009 and 2013, as shown in Figure 4.1. The real estate business seemed to recover after 2013 along with various real estate policies; the Korean government made an effort to increase housing demands and activate transactions, through the reduction of acquisition tax and transfer income tax, and the alleviation of the loan to value ratio or debt to income ratio (Cho, 2017). In the flow of the upturn of the real estate market, this study finds the net impacts of the second opening of Gyeongui Line (first extension) and the Gyeongui-Jungang Line opening (second extension) on the apartment prices.

[5] For the information on the distance and walking time, this study uses the map data from Naver, which is the Korean Internet service platform. The walking time is measured on the basis of the speed with 4 km per hour. The network distance is measured from each apartment complex to the nearest entrance of the rail stations, given spatial constraints and features.

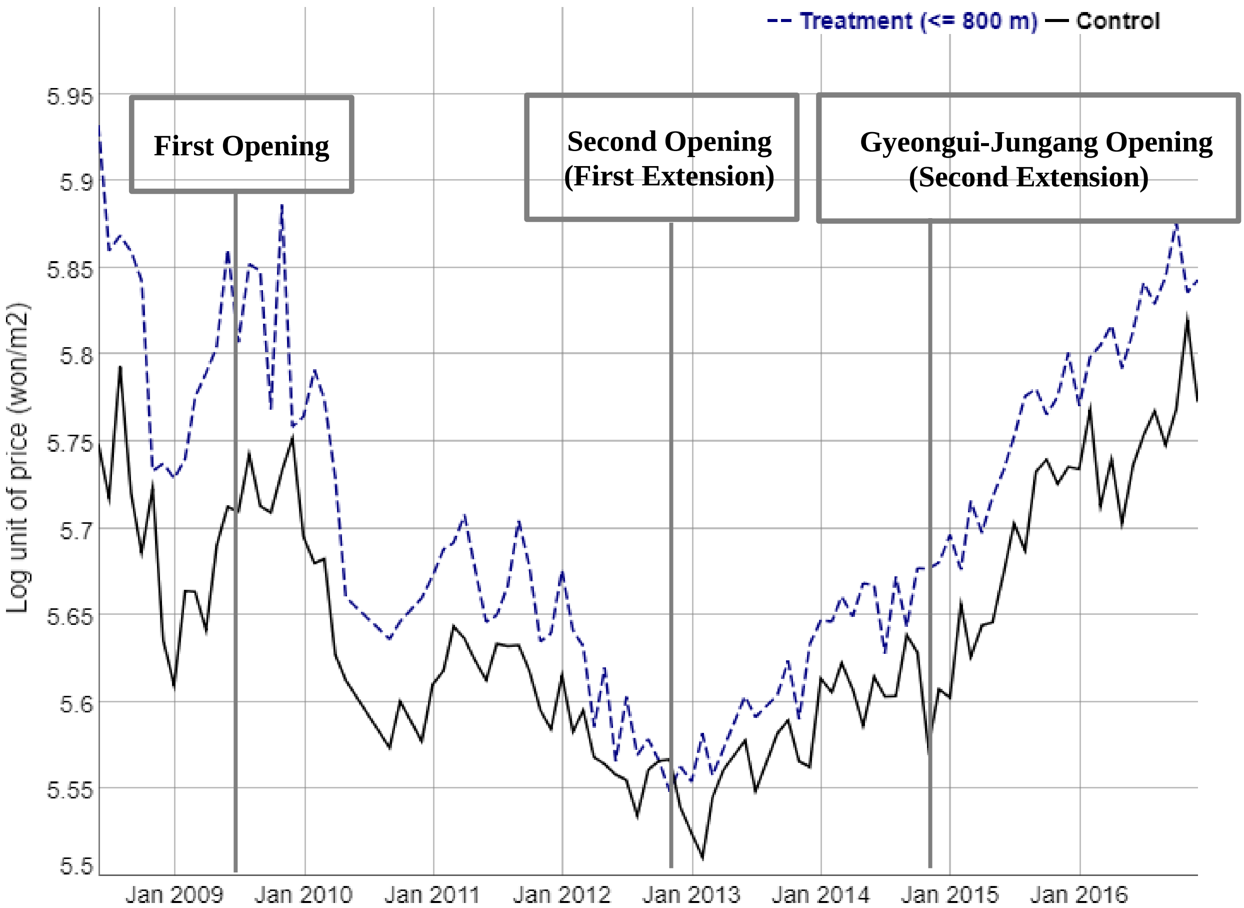

Figure 4.1 Price variations of the apartments in the treatment and control groups, from 2009 to 2015. Source: Illustrated by the author using transaction data from the Ministry of Land, Infrastructure, and Transport in South Korea.

Based on the visual inspection, this study finds when the treatment effects of the rail services were reflected to the apartment prices. To analyze the net impact of the first extension that was finished in December 2012, this study focuses on the price variations of the apartments from September 2013 to August 2014. Typically, an anticipation effect of people is reflected to housing prices before the date of completion of transport systems. Figure 4.1, however, shows no anticipation or treatment effects before the date of the opening, and the apartment prices of the two groups rather declined until December 2012. The first treatment effect would have appeared 8 months after the date of the completion, considering the price divergence of the two study groups gradually increased after August 2013. Based on this, this study compares the average apartment prices of the two study groups one year before and after August 2013.

For the second extension that was completed in December 2014, this study believes that the second treatment effect occurred a few months before the date of the completion. Korea Railroad Corporation (KORAIL) combined the route maps of Gyeongui Line and Jungang Line system in September 2014, and marked the new map as "Gyeongui-Jungang Line" with an announcement for the upcoming extension. With the assumption that an anticipation effect led to the changes in the housing values after September 2014, this study examines the price variations from October 2014 to September 2015.

4.4 Methodology

This study applies difference-in-differences (DiD) model to analyze the impacts of the first and second route extensions of the rail system. Using double differences between pre and post-intervention for both the treatment and control groups, DiD model helps to estimate the causal effect of a particular intervention by factoring out any contemporaneous changes (Lechner, 2011; Yang, 2018). This study compares the changes in the average apartment prices between the treatment group (apartments that fall within 800 m from Tanhyeon or Ilsan stations), and control group (apartments in Jungsan-dong), before and after the route extensions. The DiD model used in this study is specified as follows:

$$\mathrm{Log}(Y_{it}) = \alpha + \beta_1 Treatment_i + \beta_2 Phase_{t=1} + \beta_3 Phase_{t=2} + \beta_4 (Treatment_i \times Phase_{t=1})$$
$$+\beta_5 (Treatment_i \times Phase_{t=2}) + \beta_6 Innovation_{it} + H'_{it}\gamma + u_{it} \quad (4.1)$$

where $\mathrm{Log}(Y_{it})$ is the sale price of apartment i per square meter (m^2) in the logarithmic-term; $Treatment_i$ equals to 1 if the apartment is within 800 m from Tanhyeon or Ilsan stations, and 0 if it is in Junsan-dong; $Phase_{t=1}$ dummy variable takes a value of 1 if the period is from September 2013 to August 2014, and 0 otherwise; $Phase_{t=2}$ is another dummy variable for the second temporal change, and has a value of 1 if the period is from October 2014 to September 2015, and 0 otherwise; "$Treatment_i \times Phase_{t=1}$" and "$Treatment_i \times Phase_{t=2}$" capture the causal impacts of the first and second route extensions; β6 is a dummy variable that takes the value of 1 if the apartment i is assigned to innovation elementary school at that time and 0 otherwise; H'_{it} is a vector that involves the housing characteristics (such as construction year of apartments, floor, entrance type, area of exclusive use, the number of households, room, bathroom) and distances attributes (such as distance to elementary school and bus stop).

4.5 Falsification test

The underlying assumption of DiD estimation is that the outcome between the treatment and control groups would follow a parallel trend, in the absence of intervention. This study assumes that the price difference between the apartments in Tanhyeon and Ilsan-dongs (treatment group) and those in Jungsan-dong (control group) is constant over time, before the route extensions. For the validity of the assumption, this study conducts a falsification test by using the prior transaction data from July 2010 to July 2013. It also tests the assumption targeting small-sized and medium-large-sized apartments. This study expects that the interactions (Treatment× Phase) are statistically insignificant regardless of signs. As a result of the test, the coefficients on "Treatment × Phase" are not statistically different from zero, as shown in Table 4.3. The common trend assumption is also satisfied at all size categories, and the only "Phase" coefficients are positive and significant at less than 1%. The inclusion of other control variables also does not affect the estimates.

Table 4.3 Falsification test using the data from July 2010 to July 2013

	Log (Price per m^2)			
Size of housing	(1)	(2)	(3)	(4)
Overall size (0-135m^2)				
Treatment	.048	-.019	-.024	-.046
	(.030)	(.023)	(.021)	(.024)
Phase	-.053***	-.051***	-.052***	-.052***
	(.015)	(.014)	(.015))	(.014)
Treatment × Phase	-.028	-.022	-.022	-.034
	(.020)	(.017)	(.019)	(.018)
Constant	5.609***	-27.846***	-26.530***	-31.996***
	(.014)	(6.553)	(5.766)	(6.850)
Observations	2,833	2,761	2,761	2,761
R-squared	.117	.478	.507	.508
Housing characteristics	No	Yes	Yes	Yes
Distance attributes	No	No	Yes	Yes
Innovation	No	No	No	Yes
Small (0-60m^2)				
Treatment	.028	.025	.014	-.003
	(.031)	(.022)	(.028)	(.030)
Phase	-.021***	-.016***	-.018***	-.018***
	(.004)	(.005)	(.005)	(.005)
Treatment × Phase	-.004	-.004	-.001	-.001
	(.015)	(.015)	(.014)	(.018)
Constant	5.598***	-54.511***	-52.046***	-59.736***
	(.010)	(9.826)	(8.481)	(9.088)
Observations	1,199	1,171	1,171	1,171
R-squared	.035	.567	.586	.594
Housing characteristics	No	Yes	Yes	Yes
Distance attributes	No	No	Yes	Yes
Innovation	No	No	No	Yes
Medium-large (61-135m^2)				
Treatment	.043	-.067*	-.079**	-.099***
	(.045)	(.034)	(.029)	(.026)
Phase	-.104***	-.097***	-.097***	-.098***
	(.021)	(.019)	(.018)	(.018)
Treatment × Phase	-.002	.002	.001	-.012
	(.023)	(.020)	(.020)	(.019)
Constant	5.626***	-20.647***	-18.215***	-23.827***

	(.035)	(7.187)	(5.145)	(5.830)
Observations	1,634	1,590	1,590	1,590
R-squared	.187	.565	.596	.596
Housing characteristics	No	Yes	Yes	Yes
Distance attributes	No	No	Yes	Yes
Innovation	No	No	No	Yes

Note: The table results show the parallel trend assumption test between the treatment group (<= 800 m) and the control groups. This study examines data from July 2010 to July 2013, and tests if the outcome in the pre-treatment period follows the same trend. The estimation results are obtained through wild cluster bootstrapping, considering that there are small number of clusters (apartment complex) in the villages, and the sizes of the clusters are unbalanced (Cameron el al, 2008). Standard errors that are clustered at the apartment complex level are in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

V. Empirical Result

5.1 Impacts of the railway route extensions on the apartment prices

This study analyzes the causal effects of the first and second route extensions of the rail system on the apartment prices, by relying on DiD estimation. The estimated results are shown in Table 5.1. Based on the treatment boundary within 800 m from the rail stations, this study also tests the impacts for small-sized and medium-large-sized apartments, respectively. The dependent variable is sale price per m^2 with a logarithmic term. The first column is the baseline DiD model without the other control variables. The third column controls for both housing characteristics (such as floor, area of exclusive use, building to land ratio, age of an apartment, the number of households, room, bath, entrance type) and distance attributes (such as distance to elementary school and bus stop). The fourth column adds a dummy variable to indicate the assignment of innovation elementary schools.

For the result of overall size, the first and second network extensions increased the apartment prices in the treatment group by 2.6% and 5.9%, relative to those in the control group. The result implies that the large increase in accessibility through the second route extension created the higher capitalization effects for the apartment prices. The significant and positive coefficients on “Phase1” and “Phase2” show a rising trend of the apartment prices after the route extensions. Based on this, it was likely that the causal effects of the railway route extensions were found along with the upturn of the real estate business after 2013. Further, the prices of the apartments that are assigned to innovation schools were higher than those of the regular apartments by 4.8%.

Table 5.1 Estimation results of DiD model

	Log (Price per m^2)			
Overall size (0-135m^2)	(1)	(2)	(3)	(4)
Treatment	.013	-.038	-.043*	-.069**
	(.029)	(.020)	(.021)	(.026)
Phase1	.042***	.039***	.040***	.041***
	(.010)	(.008)	(.007)	(.006)
Phase2	.094***	.105***	.105***	.092***
	(.012)	(.009)	(.008)	(.013)
Treatment × Phase1	.028*	.027**	.027**	.026**
	(.012)	(.010)	(.009)	(.009)
Treatment × Phase2	.057***	.044***	.045***	.059***
	(.015)	(.011)	(.011)	(.016)
Innovation				.048*
				(.021)
Constant	5.551***	-22.970***	-22.847***	-28.213***
	(.019)	(5.708)	(5.380)	(6.541)
Observations	4,259	4,259	4,259	4,259
R-squared	.228	.660	.673	.686
Housing characteristics	No	Yes	Yes	Yes
Distance attributes	No	No	Yes	Yes

Note: The results are estimated using the transaction samples of the treatment (<= 800 m from the rail stations) and the control groups. “Phase1” and “Phase2” denote the temporal change of the first and second railway extensions, respectively. “Treatment × Phase1” and “Treatment × Phase2” capture the net impacts of the first and second railway extensions on the apartment prices, respectively. For consistent estimates of standard errors, this study runs wild cluster bootstrapping. The standard errors that are clustered at the apartment complex level are in parenthesis.
*** p<0.01, ** p<0.05, * p<0.1

The estimation results by size of housing are presented in Table 5.2. It uses the same specifications with the baseline model. While the first and second extensions increased the prices of small-sized properties in the treatment group by 1.9% and 4.6% as compared to those in the control group, these impacts on medium-large-sized properties increased by 3.4% and 9.9%. The higher treatment effects for medium-large-sized apartments could be due to the high rate of increase in the transactions after the route extensions relative to small-sized apartments, as shown in Table 4.2. The positive coefficients on “Innovation” at the both size categories show the higher prices of the assigned apartments than the regular apartments.

Further, this study presents a result table which shows the treatment effects for the national housing scale (area of exclusive use below $85m^2$), in appendix. The Korean government has built the national housings since the 1970s, in order to sell and rent housings at lower prices to those who cannot afford to buy housings. They have offered buyers of the national housings various tax benefits and subsidies (Choi and Jihn, 2015). The estimations show that the treatment effects of 2.5% and 5.2% were found for the national housing scale (See Appendix D).

Table 5.2 DiD estimation by size of housing

	Log (Price per m^2)			
Size of properties	(1)	(2)	(3)	(4)
Small ($0\text{-}60m^2$)				
Treatment	.021	.009	.002	-.062*
	(.031)	(.017)	(.022)	(.032)
Phase1	.049***	.058***	.056***	.056***
	(.007)	(.005)	(.005)	(.005)
Phase2	.121***	.124***	.124***	.114***
	(.004)	(.003)	(.003)	(.010)
Treatment × Phase1	.021	.016	.017*	.019*
	(.014)	(.008)	(.008)	(.008)
Treatment × Phase2	.050***	.038***	.036***	.046**
	(.014)	(.010)	(.011)	(.015)
Innovation				.086*
				(.036)
Constant	5.574***	-34.539***	-34.967***	-61.891***

	(.007)	(8.793)	(8.350)	(13.062)
Observations	1,732	1,732	1,732	1,732
R-squared	.359	.715	.726	.743
Housing characteristics	No	Yes	Yes	Yes
Distance attributes	No	No	Yes	Yes
Medium-large (61-135m^2)				
Treatment	.033	-.105***	-.114***	-.143***
	(.051)	(.027)	(.022)	(.023)
Phase1	.024	.023**	.028***	.033***
	(.020)	(.008)	(.008)	(.008)
Phase2	.070***	.080***	.081***	.050***
	(.017)	(.007)	(.007)	(.010)
Treatment × Phase1	.047*	.043***	.039***	.034***
	(.021)	(.010)	(.011)	(.010)
Treatment × Phase2	.076***	.067***	.067***	.099***
	(.019)	(.011)	(.011)	(.014)
Innovation				.060***
				(.018)
Constant	5.517***	-19.166***	-17.890***	-22.780***
	(.044)	(5.898)	(5.010)	(5.929)
Observations	2,527	2,527	2,527	2,527
R-squared	.244	.699	.713	.732
Housing characteristics	No	Yes	Yes	Yes
Distance attributes	No	No	Yes	Yes

*** p<0.01, ** p<0.05, * p<0.1

5.2 Robustness check

This study conducts a robustness test by enlarging the treatment boundaries to the rail stations. It separates the treatment zones into four sub-boundaries: 0-600 m, 600-800 m, 800-1,000 m, and 0-1,000 m. This robustness check examines how the treatment effects were estimated at the different treatment zones. The estimation results are shown in Table 5.3. All the specifications control for the housing characteristics, distance attributes, and assignment of innovation school. The treatment effect of the first extension was highest when the impact zone is between 800 m and 1,000 m, along with the capitalization effect of 3.1%. In contrast with the hypothesis of this study, the effects increased as the treatment zone moves further away from the rail stations. This could be due to other factors which affect the housing demands, such as the quality of the apartments or the location of amenities around the apartment complexes. Along with impacts of railway development projects, other studies have discussed various factors that influence housing values (Bowes and Ihlanfeldt, 2001; Song, 2015). The second route extension created the highest capitalization effect of 6% for the prices of the apartments within 600 m from the rail stations. The effects generally declined along with the decrease in the accessibility to the rail stations. Overall, the first and second extensions had significant effects on the apartment prices at the all treatment boundaries.

Table 5.3 Robustness test with different impact zones

	Log (Price per m^2)			
Overall size (0-135m^2)	0-600 m	600-800 m	800-1,000 m	0-1,000 m
Treatment	-.075* (.038)	-.085** (.029)	-.115*** (.017)	- .084*** (.025)
Phase1	.043*** (.007)	.044*** (.005)	.042*** (.007)	.041*** (.007)
Phase2	.091*** (.015)	.097*** (.013)	.093*** (.012)	.090*** (.014)
Treatment × Phase1	.022* (.010)	.025* (.011)	.031*** (.008)	.028*** (.008)
Treatment × Phase2	.060** (.018)	.052*** (.018)	.048** (.016)	.055*** (.015)
Constant	-31.367** (9.804)	-31.419*** (7.228)	-38.809*** (5.115)	-33.710*** (6.486)
Observations	3,098	2,763	3,542	6,199
R-squared	.694	.698	.736	.686
Housing characteristics	Yes	Yes	Yes	Yes
Distance attributes	Yes	Yes	Yes	Yes
Innovation school	Yes	Yes	Yes	Yes

Note: This robustness test only addresses overall size (0-135m^2). The estimation results for small-sized and medium-large-sized apartments at the different impact zones are presented in appendix.
*** p<0.01, ** p<0.05, * p<0.1

5.3 Heterogeneity effect

Lastly, this study identifies heterogeneity effects by regional groups. Given the different development levels and regional characteristics by the villages, it separates Tanhyeon and Ilsan-dongs into different treatment groups, and compares the apartment prices with those in the control group, respectively. Table 5.4 shows the estimation results of the first group (Tanhyeon and Jungsan-dongs) and the second group (Ilsan and Jungsan-dongs). All the specifications include the housing characteristics and distance attributes, and the assignment of innovation elementary schools.

Table 5.4 Heterogeneity effect by regional groups

Size of properties	Group 1: Tanhyeon || Jungsan (1)	Group 2: Ilsan || Jungsan (2)
Overall size (0-135m^2)		
Treatment	-.056*	-154***
	(.024)	(.020)
Phase1	.042***	.044***
	(.006)	(.006)
Phase2	.096***	.096***
	(.014)	(.012)
Treatment × Phase1	.021*	.032***
	(.010)	(.009)
Treatment × Phase2	.056***	.054***
	(.016)	(.014)
Innovation	.033*	.038***
	(.014)	(.010)
Constant	-23.05***	-51.78***
	(10.27)	(4.90)
Observations	3,139	2,722
R-squared	0.677	0.756
Housing characteristics	Yes	Yes
Distance attributes	Yes	Yes
Small (0-60m^2)		
Treatment	-.009	-.080***
	(.011)	(.023)
Phase1	.058***	.056***

	(.005)	(.005)
Phase2	.121***	.120***
	(.006)	(.007)
Treatment × Phase1	.024*	.010
	(.010)	(.012)
Treatment × Phase2	.056***	.018
	(.010)	(.015)
Innovation	.032***	.035***
	(.006)	(.008)
Constant	-14.24***	-82.96***
	(5.16)	(11.26)
Observations	1,390	1,280
R-squared	0.684	0.763
Housing characteristics	Yes	Yes
Distance attributes	Yes	Yes
Medium-large (61-135m^2)		
Treatment	-.136***	-.208***
	(.014)	(.021)
Phase1	.033***	.031***
	(.006)	(.007)
Phase2	.057***	.050***
	(.007)	(.008)
Treatment × Phase1	.025*	.049***
	(.012)	(.008)
Treatment × Phase2	.088***	.104***
	(.015)	(.012)
Innovation	.051***	.056***
	(.011)	(.009)
Constant	-19.16***	-57.33***
	(4.30)	(6.78)
Observations	1,749	1,442
R-squared	0.751	0.797
Housing characteristics	Yes	Yes
Distance attributes	Yes	Yes

*** p<0.01, ** p<0.05, * p<0.1

For overall size at the first group, the first and second network extensions increased the apartment prices in Tanhyeon-dong by 2.1% and 5.6%. At the second group, the apartment prices in Ilsan-dong increased by 3.2% and 5.4%, relative to those in Jungsan-dong. As for small-sized housing, the treatment effects of 2.4 % and 5.6 % were found in Tanhyeon -dong after the route extensions, while there was no significant effect in Ilsan-dong. One possible explanation is that innovation elementary school highly affected the demands of potential housing buyers who have children of elementary school-age. Considering educational environment for children could be a primary concern for the housing buyers in their 30s or 40s, there would have been the high demands for housings in Tanhyeon or Jungsan-dongs that have innovation elementary schools, rather than Ilsan-dong. Other studies have discussed the difference in housing price due to the quality of schools or the location of educational facilities (Crone, 1998; Cho, 2011). Meanwhile, for medium-large-sized apartment, this study found strong treatment effects of 4.9% and 10.4% in Ilsan-dong at the 1% significance level, relative to those of 2.5% and 8.8% in Tanhyeon-dong. This could be due to the difference in the residential environments for the middle-aged in Tanhyeon and Ilsan-dongs. It is likely that the middle-aged pay more attention to their health, and use private cars more than other age groups. Ilsan-dong allows easy access to other areas by car through Goyang Boulvard, and has neighboring medical facilities (such as a health center and medium-scale hospitals) around the apartment complexes. Those favorable residential conditions for the middle-aged might have led to the higher demands for medium-large-sized apartments in Ilsan-dong.[6]

VI. Conclusion

This study estimates the causal impacts of the first and second route extensions of Gyeongui-Jungang Line system on the apartment prices in the north of Ilsan district, by using

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[6] Refer to Table 3.3

DiD estimation. It supports the previous studies analyzing the effects of rail service developments on housing prices in the metropolitan areas of South Korea (Choi and Sung, 2011; Bae, 2017; Hwang and Chung, 2018; and others). Overall, the first and second route extensions had positive effects on the apartment prices in the treatment group. The prices of medium-large-sized apartments received the higher treatment effects than those of small-sized apartments after the route extensions. The results were robust to the different geographical treatment boundaries to the rail stations. Further, the different treatment effects were found by region and time.

The findings of this study show that the route extensions of the existing rail service could bring positive capitalization effects to the apartment prices in the metropolitan areas. The route extensions expanded the accessibility benefits of people, and led to the rise in the property values at the northern metropolitan area. This case study could help urban policy makers implement rail policies at other metropolitan areas, with the purpose of improving traffic conditions and increasing regional values. Additionally, the information on the price variations of the apartments would help housing investors or buyers anticipate timing to purchase housings in the area.

Lastly, this study needs further discussions. First, for more precise impact evaluation, comparative studies analyzing the effects of Gyeongui-Jungang Line for the other metropolitan areas would be needed. This is because spatial characteristics and levels of development are different by region and time. Regarding the recent transport policies in South Korea, the GTX (Great Train Express) services are expected to highly increase accessibility to distant areas, and promote residential and commercial developments around rail stations. Accordingly it will have significant impacts on property values at many metropolitan areas. Comprehensive researches on the land use pattern or development of station-influence area would be required for an effective implementation of the projects.

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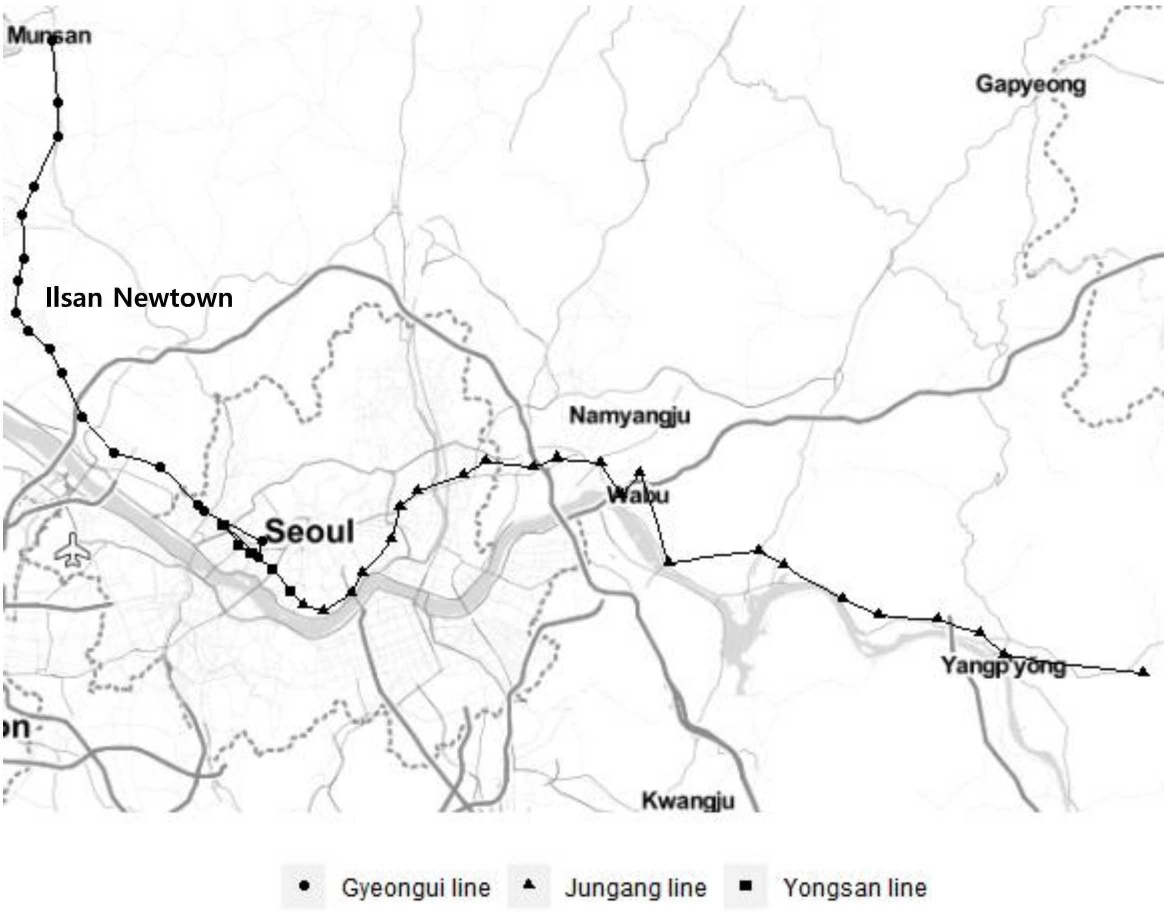
Appendices

Appendix A. Route of Gyeongui-Jungang Line



Appendix B. Information on apartment complexes

Treatment group (Tanhyeon, Ilsan dong)		**Control group (Jungsan dong)**
400-600 m	Kunyoung Apts.5 Gyeognam Apts.1 Buyeong Apts.3 Samik Apts.2 Dongsin Apts.11 Ilsan Hyundai Apts.1 Ilsan Hyundai Apts.2 Ilsan Dongyang Apts. Ilsan World Merdian Apts. Ilsan Taeyoung Apts.	Doosan Apts.1 Kolon Apts.2 Ilsin-Kungyoung Apts.3 Kunyoung-Dongbu Apts.5 Taeyoung Apts.6 Kolon Apts.7 Daewoo Apts.8 Hansung Apts.9 Kyungnam Apts.10 Hyundai Apts. 11

600-800 m	Kunyoung Apts.4 Hansin Apts.6 Samhwan Apts.13 Seogwang Apts.12 Jueun Apts.14, Sinwon-1st Singwon-2nd , Ilsin-samik Apts. Ilsan-Dongmun Apts.2 Sandeul Apts.5	Hyundai Apts. 12 Sandeul-1st Apts. Sandeul-2nd Apts.
800-1,000 m	Daerim-Hyundai Apts. Dongsung Apts.8 Ilsan Dongmun-1st Apts. Hyosung Apts.15 Poongrim Apts.16 Ssangyong Apts.9 Ilsan Hyundai Apts.3 Ilsan-Dongmun Apts.3 Ilsan-Dongmun Apts.5 Sandeul Apts.3 Sandeul Apts.6	

Appendix C. Summary statistics of small-sized and medium-large-sized housings

Small size (0-60m²)

	Full Sample		**Treatment Group (Within <= 800 m from rail stations)**		**Control Group (Jungsan-dong)**	
Observation	1,732		794		938	
	Mean	SD	Mean	SD	Mean	SD
Sale Price (won)	158,351,328	25,534,278	163,632,872	28,017,917	153,880,600	22,281,942
Sale Price per square meter (won/m²)	2,887,203	320,084	2,971,582	393,162	2,815,777	217,511
Ln (Sale price per square meter)	56,596	1,068	56.858	1,290	56,374	769
Area of exclusive use (m²)	54.91	6.76	55.07	5.77	54.78	7.50
Construction year	1996	3.14	1998	4.14	1995	0
Floor	8	5.09	10	5.72	6	3.54
Number of households	664	235.10	522	194.26	784	196.34
Apartment Complex	9	5.57	5	2.56	13	4.64

Building to land ratio (%)	19.96	12.58	25.12	16.77	15.6	3.56
Distance to rail station (m)	1,407	787.61	567	140	2,117	162.73
Distance to elementary school (m)	286.87	104.95	251	72.20	317.24	117.99
Distance to bus stop (m)	143.52	63.13	138.48	77.64	147.78	47.14

Medium & large size (61-135m^2)

	Full Sample		**Treatment Group (Within <= 800 m from rail stations)**		**Control Group (Jungsan-dong)**	
Observation	2,527		1,863		664	
	Mean	SD	Mean	SD	Mean	SD
Sale Price (won)	243,262,050	44,168,664	235,642,780	40,087,732	264,639,600	47,944,407
Sale Price per square meter (won/m^2)	2,769,175	349,347	2,824,415	323,853	2,614,188	371,210
Ln (Sale price per square meter)	56,155	1,288	56,368	1,165	55,561	1,424
Area of exclusive_use (m^2)	88.89	19.06	83.75	13.75	103.32	23.89
Construction year	1999	3.77	1999	3.81	1996	2.63
Floor	10	5.94	10	6.14	8	4.72
Household	637	230.43	671	244.09	540	149.63
Complex	7	2.37	7	2.23	9	2.27
Building to land ratio (%)	18.26	2.43	17.56	1.91	20.19	2.66
Distance to rail station (m)	939.45	530.49	643.04	125.51	1771.08	297.36
Distance to elementary school (m)	316.23	167.69	313.32	161.42	324.41	184.04
Distance to bus stop (m)	151.22	50.49	148.51	52.24	158.81	44.35

Appendix D. Treatment effects for the national housing scale

	Log (Price per m^2)			
National housing scale (0-85m^2)	(1)	(2)	(3)	(4)
Treatment	-.010	-.025	-.031	-.060*
	(.006)	(.021)	(.022)	(.027)

Phase1	.042***	.046***	.046***	.047***
	(.007)	(.008)	(.008)	(.006)
Phase2	.114***	.118***	.118***	.106***
	(.006)	(.005)	(.005)	(.011)
Treatment × Phase1	.031***	.026**	.026**	.025**
	(.008)	(.009)	(.009)	(.008)
Treatment × Phase2	.046***	.040***	.040***	.052***
	(.008)	(.009)	(.009)	(.013)
Innovation				.051*
				(.021)
Constant	5.579***	-20.195***	-20.283***	-25.730***
	(.005)	(5.339)	(4.688)	(7.148)
Observations	3,703	3,703	3,703	3,703
R-squared	.308	.601	.612	.629
Housing characteristics	No	Yes	Yes	Yes
Distance attributes	No	No	Yes	Yes

*** p<0.01, ** p<0.05, * p<0.1

Appendix E. Treatment effects by size of housing, at different impact zones

	Log (Price per m^2)			
Size of properties	0-600 m	600-800 m	800-1,000 m	0-1,000 m
Small-sized				
Treatment	.184***	-.110***	.039**	-.094***
	(.043)	(.020)	(.014)	(.019)
Phase1	.060***	.053***	.057***	.055***
	(.005)	(.008)	(.005)	(.005)
Phase2	.132***	.116***	.120***	.113***
	(.004)	(.009)	(.006)	(.001)
Treatment × Phase1	.005	.039***	.026***	.023***
	(.009)	(.011)	(.006)	(.006)
Treatment × Phase2	.024	.052***	.039***	.045***
	(.015)	(.015)	(.009)	(.012)
Constant	5.895***	-50.905***	6.144***	-59.204***
	(.102)	(14.094)	(.041)	(11.406)
Observations	1,477	1,193	1,772	2,566
R-squared	.708	.614	.728	.686
Housing characteristics	Yes	Yes	Yes	Yes
Distance attributes	Yes	Yes	Yes	Yes
Innovation school	Yes	Yes	Yes	Yes

Medium-large-sized				
Treatment	-.136***	-.153***	-.153***	-.135***
	(.031)	(.022)	(.018)	(.017)
Phase1	.033***	.031***	.030***	.031***
	(.008)	(.006)	(.006)	(.008)
Phase2	.048***	.064***	.053***	.056***
	(.013)	(.008)	(.012)	(.010)
Treatment × Phase1	.036***	.031**	.029**	.033***
	(.011)	(.011)	(.009)	(.009)
Treatment × Phase2	.103***	.080***	.071***	.082***
	(.018)	(.014)	(.016)	(.012)
Constant	-25.530***	-24.151***	-32.684***	-25.582***
	(6.363)	(5.455)	(6.054)	(5.187)
Observations	1,621	1,570	1,770	3,633
R-squared	.742	.784	.767	.724
Housing characteristics	Yes	Yes	Yes	Yes
Distance attributes	Yes	Yes	Yes	Yes
Innovation school	Yes	Yes	Yes	Yes

*** p<0.01, ** p<0.05, * p<0.1